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USNRDL-TR-118

RADIOTOXICITY RESULTING FROM EXPOSURE TO FALLOUT SIMULANT

II. THE METABOLISM OF AN INHALED AND INGESTED SIMULANT OF FALLOUT PRODUCED BY A LAND-BASED NUCLEAR DETONATION

Research and Development Technical Report USNRDL-TR-118
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U.S. NAVAL RADIOLOGICAL DEFENSE LABORATORY

SAN FRANCISCO 24, CALIFORNIA

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Health and Biology

Technical Objective
AW-6

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ABSTRACT

The present study was designed to reproduce in the laboratory an acute exposure of mice to early fallout (2 days old) such as might result from a land-based nuclear detonation. Biological data were obtained on the uptake, distribution, and retention of the inhaled fallout simulant. Further, as a basis for comparing the effects of different types of simulants, the metabolic behavior of this dry-particle fallout simulant of limited solubility was compared to that of two previously studied fallout simulants; an ionic liquid aerosol and a mud-slurry aerosol. The simulant was also administered by gavage to provide data on uptake of fallout by ingestion as compared with inhalation. From these data, an evaluation was made of the radiation dose to individual tissues from inhaled fallout as compared to the concomitant external radiation dose that the animals would receive if exposed to the same airborne simulant.

SUMMARY

The Problem

The present study was designed to reproduce in the laboratory an acute exposure of mice to early fallout (2 days old) such as might result from a land-based nuclear detonation. Biological data are required on the uptake, distribution and retention of the inhaled fallout simulant. Further, as a basis for comparing the effects of different types of simulants, the metabolic behavior of this dry-particle fallout simulant of limited solubility must be compared with that of two previously studied fallout simulants. The simulant administered by gavage provides data on the uptake of fallout by ingestion as compared with inhalation.

These data are required for an evaluation of the radiation dose to individual tissues and organs from inhaled fallout as compared with the concomitant external radiation dose that the animals would receive if exposed to the same airborne simulant.

Findings

Following a 3-hr exposure to a dry-particle simulant of a land-based nuclear detonation, the activity was quickly cleared from the lungs and appeared primarily in the gastrointestinal (GI) tract. Lesser concentrations of activity were also found in the head, liver, skeleton and thyroid. The radioactivity was removed very rapidly from the GI tract, as compared to the rate of loss of the simulant from the respiratory system.

The ratio of activity in the GI tract to that in the respiratory system following exposure to the ionic, mud-slurry and dry-particle simulants was 3.2, 12, and 80, respectively. The rate of biological elimination of the dry-particle simulant material from the skeleton and liver was considerably greater than was noted with the previously studied ionic simulant. In terms of total respiratory and GI tract activity at 1 hr, the skeletal activity was twice as high for the ionic simulant as for the dry-particle simulant, while the reverse was true for the liver activity.

Following the administration of the simulant by gavage, the initial distribution of activity in the GI tract and in the tissues was very similar to that following inhalation exposure. It was found that the absorption across the GI tract provided an important portal of entry for the dry-particle simulant into the systemic circulation following an inhalation exposure. The composition of the simulant material in the various tissues during the first 4 days following exposure appears to be dominated by one or a group of fission products, as seen from the similarity of the radioactive decay rates for most of the tissues. The results were similar for both inhalation exposure and administration by gavage. Exceptions to these findings were the thyroid and the skeletal tissues, the former having an affinity for the short-lived iodine isotopes and the latter for the longer-lived fission products.

The thyroid received the highest dose to any tissue from the internally deposited fission products. The GI tract received the next highest dose which was, however, less than 10 per cent of the dose to the thyroid. The dose to the skeleton, while lowest in the 15-day period studied, will probably be greater than that to other tissues over a longer period of time, since the skeletal activity falls off more slowly than that in other tissues. The internal radiation dose to individual tissues was, with the exception of the dose to the thyroid, lower than the concomitant external dose received by the animals.

ADMINISTRATIVE INFORMATION

This work was done as a part of Bureau of Medicine and Surgery Project Number NM 006-015.04, Phase 1, Technical Objective AW-6, as described in the U.S. Naval Radiological Defense Laboratory Research Progress Report to the Bureau of Medicine and Surgery, NAVMED 1343, of 31 December 1955.

The work also is part of the technical program for the Department of the Army established between Department of the Army, Office, Chief of Research and Development, and Bureau of Ships (Joint Agreement, 23 November 1955).

Acknowledgment

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INTRODUCTION

Exposure to fallout from a nuclear detonation, or to an aerosol formed in controlled nuclear fission, results in a biological hazard both from the external radiation of the organism and from radiation emanating from internally deposited material. Previous studies have indicated that the short-term effects which appear following a combined exposure (i.e., external and internal exposure) result primarily from the external radiation. The amount of material sufficiently great to penetrate the natural filtering defenses of the living organism and produce immediate effects is necessarily associated with a very large amount of external radioactive material. There are, however, situations in which the internal radiation is of primary concern. Such situations include the long-term effects produced by internally deposited isotopes with long radioactive and biological half-lives; long-term effects of accumulated small doses of short-lived as well as long-lived isotopes; and damage to individual tissues resulting from selective localization of isotopes.

In order to assess these situations, it is necessary to understand the metabolism of the fission products, i.e., the uptake, distribution, and retention in the body of the various isotopes which are inhaled and ingested. While a number of the long-lived fission products have been studied,[1-3] information is lacking in two areas: first, on the metabolism of a very early fission-product mixture (which includes many short-lived fission products) and secondly, on the behavior of longer-lived fission products competing in the body metabolism with the numerous other fission products found in the spectrum formed on bombardment of uranium. The behavior of an isotope administered singly may differ from the isotope taken in a mixture of fission products.

While physical instrumentation can be used to determine the external dose to an organism, it is not sufficient for calculating the internal exposure since complementary metabolic data are lacking on the quantity of internally deposited material in particular tissues and organs and on their turnover rates as a function of the amount present in the external environment.

In the present experiment, therefore, a direct evaluation was made of the uptake and distribution of fission products deposited internally

in mice as a result of exposure to a dry-particle simulant incorporating 2-day old fission material. The simulant employed was composed of tracer amounts of fission-product chlorides adsorbed completely on dirt particles in a wide size range. The simulant was generated as airborne particulates and represents, qualitatively, the fallout which might be encountered as a consequence of a land-based nuclear detonation. The simulant is, however, not necessarily of the same chemical form as fallout which would tend to maximize the hazard as approximated here.

Earlier studies have traced the fate of two other types of simulants—an ionic simulant[4] and a mud slurry simulant.[5] The former represents the fallout that might occur following a nuclear detonation in sea water, and the latter a detonation in a shallow harbor. The biological response to an exposure to fallout is dependent on the properties of the carrier material. The results obtained with the dry-particle simulant in the present experiment were compared with results obtained with other types of simulants produced in previous studies.

In order to assess the relative importance of inhalation and ingestion as modes of entry for the fission products into the body, the dry-particle simulant was administered to mice by gavage and the response to this mode of administration was compared with that following inhalation exposure.

EXPERIMENTAL

Preparation of the Simulant

The simulant was prepared from neutron-irradiated uranium obtained from the Materials Testing Reactor. * The mixture of fission-products was dissolved in HCl and added to a solution of previously prepared dirt particles of Ambrose clay loam of less than 40 microns in diameter.[6] The particle-fission-product mixture was evaporated to dryness in a ball mill to insure mixing. The resultant simulant consisted of dirt particles with an average diameter of from 1 to 5 microns with the fission products adsorbed on the surfaces. The solubility of the activity adsorbed on the clay particles was 8 per cent in water and 18 per cent in HCl at pH = 1. The animals were exposed to this simulant within 2 days after the removal of the irradiated uranium from the reactor.

* Materials Testing Reactor Irradiation Service, Phillips Petroleum Co., Idaho Falls, Idaho.

Aerosol Generation

The experimental apparatus for generating the aerosol and exposing the animals (see Fig. 1) was previously described.[4,6] The equipment consisted of: (1) an aerosol generator, (2) the animal exposure chamber, (3) sample collectors for collecting particles (for determination of size and aerosol concentration) and (4) supporting equipment (pump, etc.).

A generator was designed to provide a stream of airborne dry particles at a constant concentration level (3.2×10^{-2} μc/ml).[6] The rotation of the outer tube provided a constant advance of a brush against the surface formed by the dry particles. The particles thus agitated were picked up by the airstream and delivered to the exposure chamber at a flow rate of 20 cu ft/hr.

In the present study, 48 mice were exposed to the dry-particle-fallout simulant in a manner identical to that used with the ionic simulant.[4] In addition, a solution containing a measured amount of the dry simulant was administered by stomach tube to 36 mice.

The animals were sacrificed in groups of 6 each, starting at 1 hr after exposure and at various intervals up to 15 days. The experimental procedure for measuring the activity of the fission products in the tissues has been described in a previous report.[4]

The distribution of gamma activity was determined in the following organs and tissues: respiratory tract (starting at the upper end of the larynx) and lungs, liver, tibia, thyroid, head,and GI tract and contents (from top of esophagus to anal region). The autopsies were carried out with care to avoid cross contamination.

The tissue assays were performed by determining the gamma activity with a sodium iodide gamma scintillation counter. The tissues were mounted in Coors porcelain crucibles and positioned under the crystal. Beta activity was not measured due to the inherent difficulties with preparation of samples for counting. However, previous experiments have shown that the gamma activity measurements satisfactorily reflect the total fission-product activity.

RESULTS AND DISCUSSION

Initial Uptake of the Inhaled Aerosol by Animal Tissues

The distribution of the radioactive fallout simulant in the tissues and organs of mice exposed to the airborne simulant for 3 hr, and serially

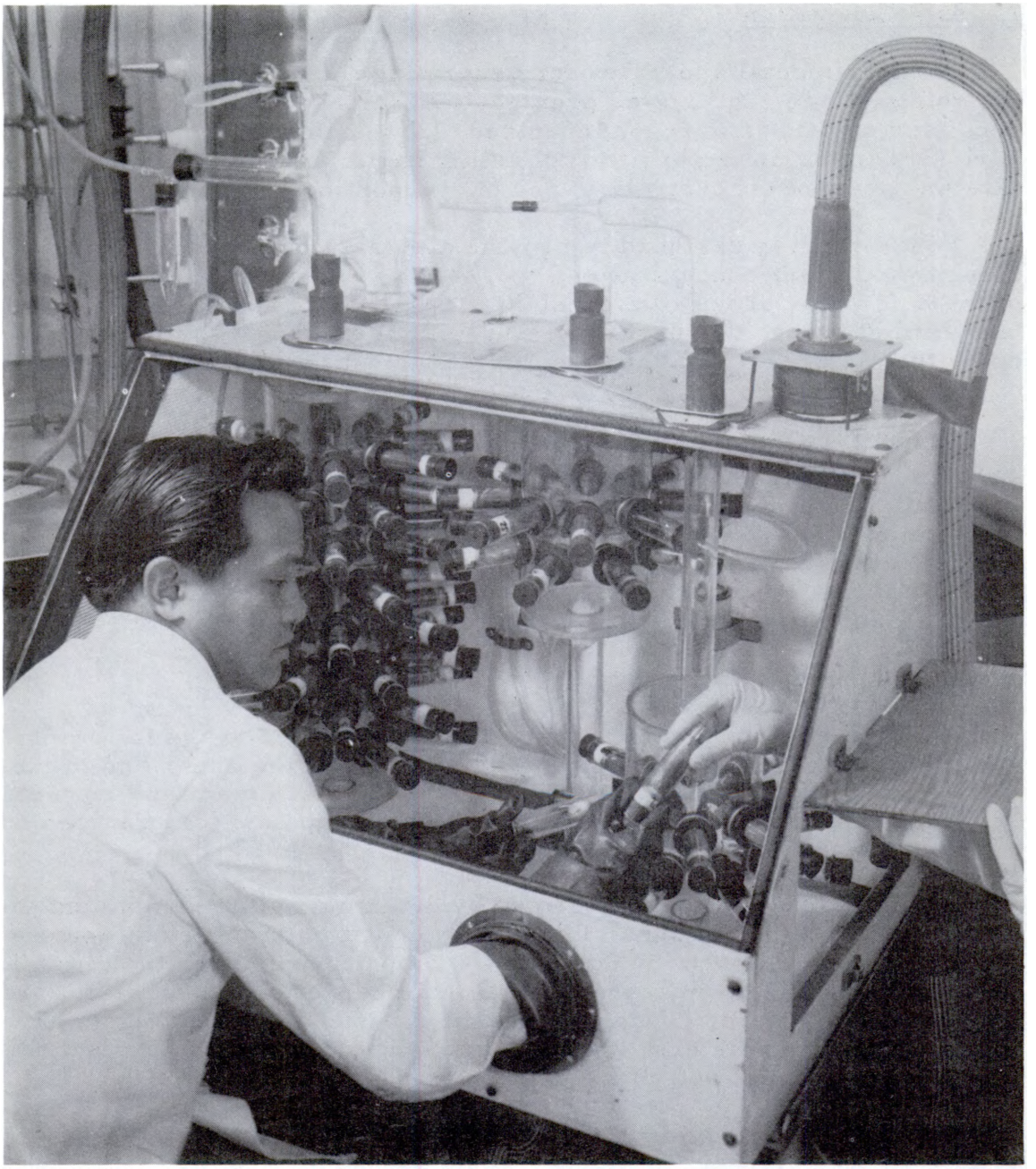

Fig. 1 Mouse Inhalation Chamber. Method of exposing mice to radioactive aerosol is illustrated.

sacrificed at periods ranging from 1 hr to 15 days following exposure, is shown in Fig. 2. At 1 hr after exposure, approximately 90 per cent of the internal activity (as determined by gamma activity measurements) was found in the GI tract, although all the activity originally entered the body by inhalation. It appears that most of the radioactive material was associated with large particles which presumably were rapidly moved back up the respiratory tract by ciliary action and swallowed, while the smaller particles penetrated to the alveolar tissue. A small but significant fraction of the material in the GI tract was absorbed into the body following either inhalation or gavage; the remaining material was excreted. By the third day only 1 per cent of the maximum activity in the GI tract remained.

The major portion of the radioactive substance which entered the systemic circulation did so in a matter of hours. Loss of activity from the blood was very rapid. At 1 hr the activity in the liver was approximately 2 per cent of the activity in the GI tract, while both the respiratory tract (including lung) and skeleton contained approximately 1.2 per cent of the activity. The thyroid contained 0.2 per cent of the GI tract activity and the head 9 per cent. The high level of activity in the head probably reflects the presence of large particles which were inhaled and trapped in the nasal passages.

The initial distribution of activity differs markedly from that observed following exposure of mice to the ionic liquid aerosol[4] and the slurry type aerosol[5] (see Table 1). On the basis of the activity found in the respiratory tract being 1, the activity of the GI tract was 80 $\pm$ 13 for the dry-particle simulant (Type III), as compared to 3.2 $\pm$ 0.3 for the liquid aerosol (Type I), and 12 $\pm$ 1.1 for the ionic-mud slurry aerosol (Type II).

If the total activity found in both the respiratory tract and the GI tract is used as the basis for comparison, the amount of activity retained at 1 hr in the skeleton is 2.3 $\pm$ 0.1 per cent with the Type I simulant and only 1.3 $\pm$ 0.1 per cent with Type III, suggesting that the dry particles may not be as available to bone as the ionic form. On the other hand, the activity retained by the liver when the animal is exposed to Type III simulant (again in terms of total GI and respiratory tract activity) was 1.9 $\pm$ 0.1 per cent as compared to 1.1 $\pm$ 0.1 per cent for Type I. The higher retention of the particulate simulant by the liver is probably associated with the natural function of particle entrapment by the reticuloendothelial system. These findings suggest that the particulate aerosol retains its adsorbed fission products in the body.

Initial Uptake of Ingested Simulant

In the experiment in which the dry-particle simulant was fed the mice by stomach tube, the initial distribution of activity in the GI tract and in the soft tissues and skeleton is very similar to that following inhalation

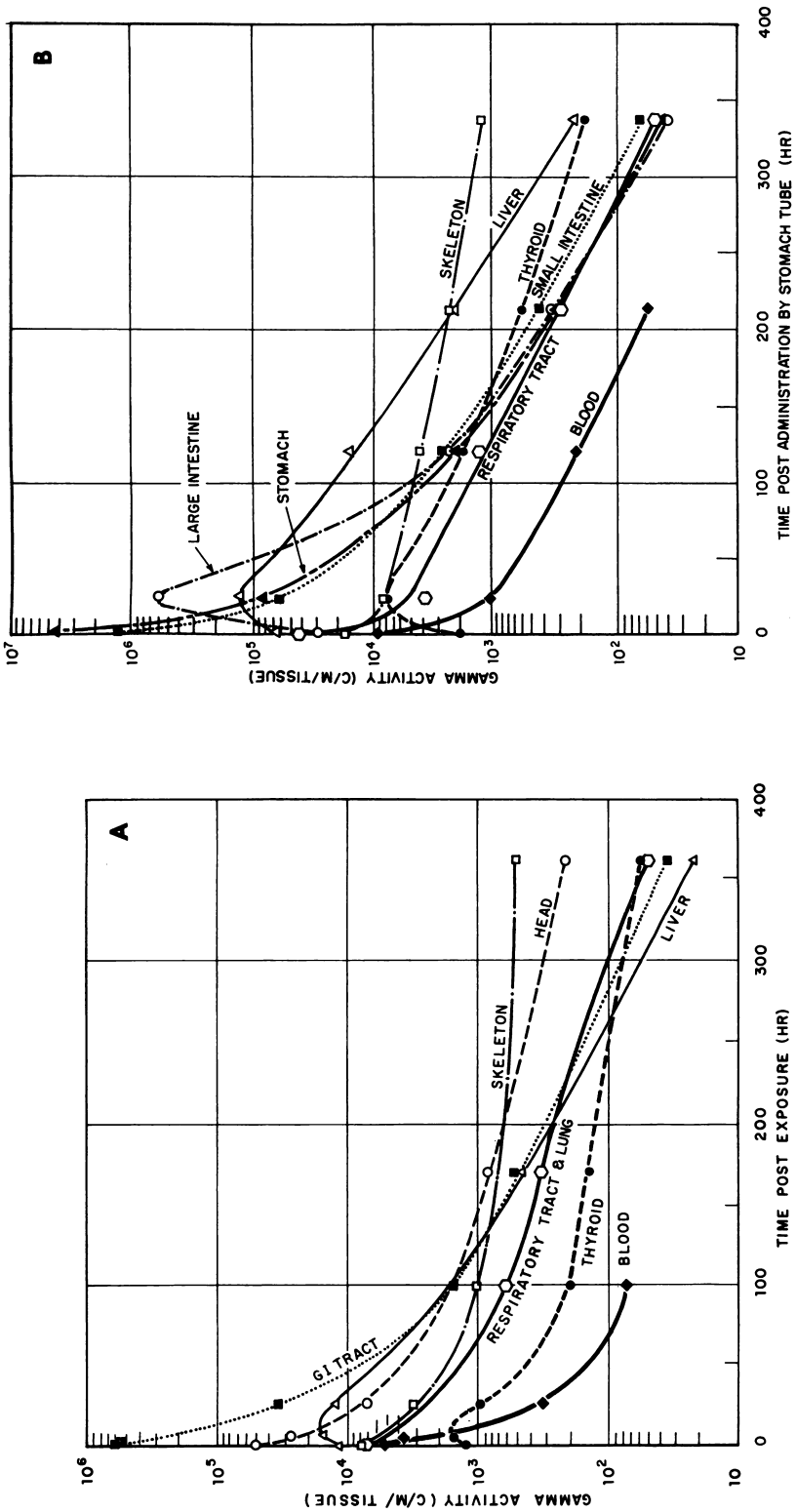

Fig. 2 Uptake and Retention of Gamma Activity in Mice Following:

A. Exposure to Simulant III Aerosol

B. Administration of Simulant III by Gavage

TABLE 1

Distribution of Activity in Mice 1 Hr After Exposure to Fallout Simulants

Tissue	Type of Fallout Simulant		
	I Ionic	II Ionic-Mud Slurry	III Dry Particles
Respiratory Tract and Lung[a]	1	1	1
Gastrointestinal Tract and Contents	3.2 ± .3	12 ± 1.1	80 ± 13
Skeleton	0.096 ± .011	0.22 ± .04	0.99 ± .23
Head	0.28 ± .064	1.1 ± .26	6.7 ± .76
Liver	0.043 ± .007	0.31 ± .15	1.5 ± .71
Thyroid	0.0083 ± .003	0.028 ± .015	0.15 ± .07

(a) Respiratory tract activity is expressed as 1. All other values are expressed in terms of ratio to respiratory tract activity.

TABLE 2

Distribution of Activity in Mice at 1 Hr Following Administration of the Dry-Particle Simulant

Tissue	Method of Administration of Simulant	
	Inhalation	Gavage
Gastrointestinal Tract and Contents[a]	1	1
Respiratory Tract and Lung	0.0125 ± .002	0.0064 ± .001
Skeleton	0.0124 ± .001	0.0028 ± .001
Liver	0.0194 ± .004	0.010 ± .003

(a) Gastrointestinal tract activity is expressed as 1. All other values are expressed in terms of ratio to gastrointestinal tract activity.

exposure (Fig. 2B). The comparison of the amount of activity in the various tissues following inhalation and gavage of the Type III simulant is presented in Table 2. Following gavage, approximately 1.3 ± 0.2 per cent of the activity in the GI tract at 1 hr gained entry into the blood stream and was retained by the liver and skeleton, the primary sites of internal deposition of the simulant. In comparison, about 3.2 ± 0.3 per cent of the GI tract activity was found in the liver and skeleton following the inhalation exposure to the same simulant. Thus, absorption from the GI tract accounts for an average of 23 per cent of the activity deposited in the skeleton following an inhalation exposure, and 50 per cent of both the liver and respiratory tract activity. Only half the activity in the respiratory system, therefore, derives from material directly inhaled and absorbed through the alveolar tissue; the other half is obtained from material which enters the circulation upon absorption through the GI tract. These data emphasize the fact that the GI tract is a significant portal of entry of a dry-particle aerosol into the systemic circulation following an inhalation exposure. Thus, the physical characteristics (such as particle size) which have to be considered in evaluating the absorption of particles must be considered with respect to the intestinal membranes as well as the alveolar tissue.

The radioactivity in all the tissues except the skeleton and thyroid following both inhalation and gavage decayed rapidly, decreasing to a fraction of 1 per cent of their 1 hr activity by the 15th day. The skeleton and thyroid, however, retained from 4 to 9 per cent of their 1 hr activity at the 15th day. The drop in activity in each tissue was a function of two simultaneous processes: the radioactive decay of the fission products and the biological loss of the simulant material itself from the tissues.

Radioactive Decay of Tissue Activity

The composition of the radioactive material deposited in a tissue is reflected in the radioactive decay curve of that tissue. In order to gain information on the selective uptake, the gamma activity of the tissues of animals sacrificed at 1 hr post-exposure was measured at intervals over a 30-day period. These decay curves for various tissues (following administration by both inhalation and gavage) are shown in Fig. 3. The similarity of the curves (with the exception of the skeleton) indicates that the isotopic distribution of the internally deposited fission products in most of the tissues was very similar. The lower rate of decay of the activity in the skeletal tissue reflects a fractionation in the uptake of the fission-product mixture due to the affinity of bone for certain of the elements which are characterized by relatively long half-lives. The activity of material deposited in the liver decayed with a somewhat higher rate than other soft tissues. The apparent increase in activity at 1 day probably reflects the growth of a gamma-emitting daughter from a beta-emitting parent radionuclide.

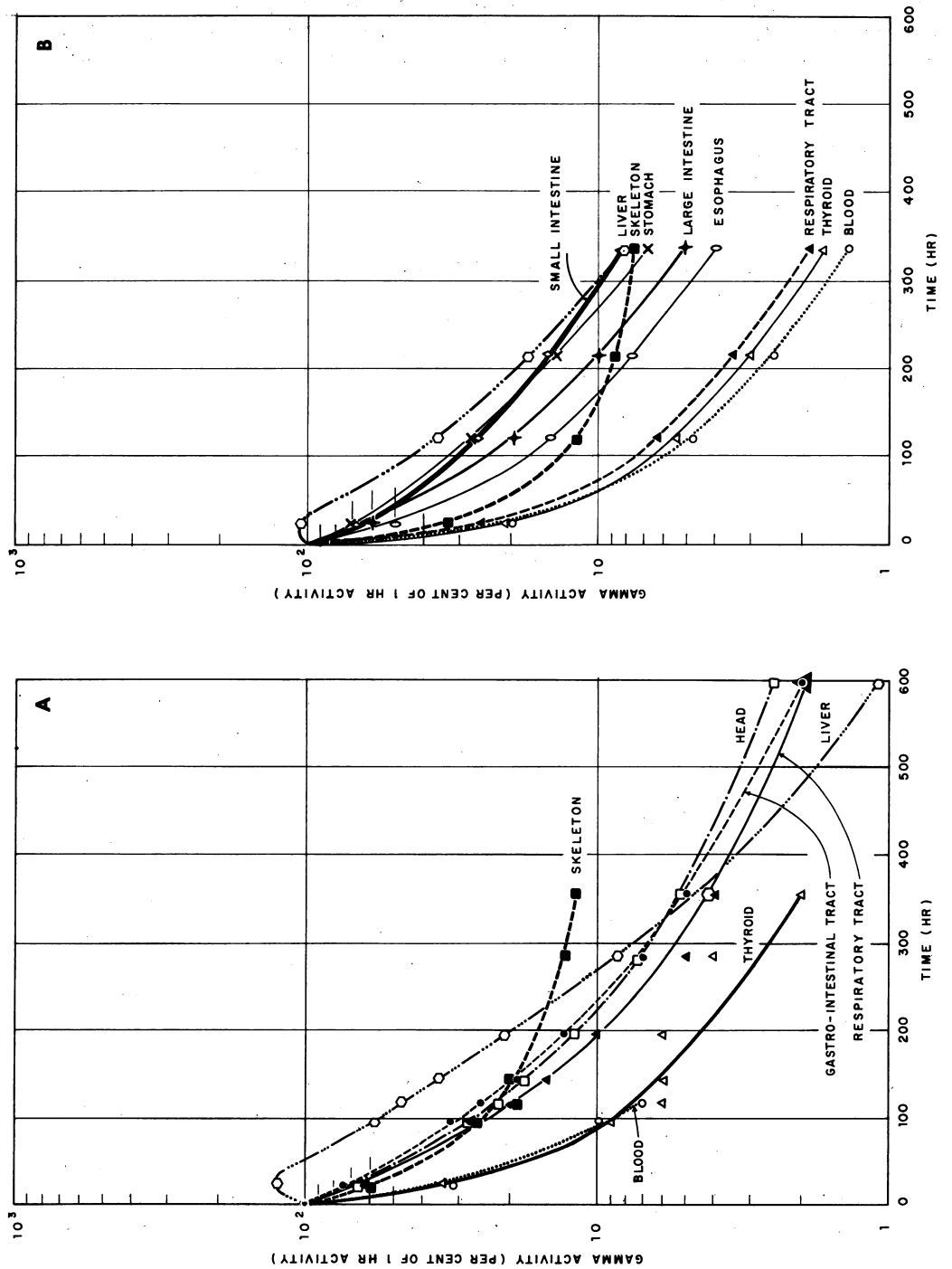

Fig. 3 Radioactive Decay of Gamma Activity of Tissues of Animals Following:

A. Inhalation Exposure

B. Administration of Simulant by Gavage

The composition of the fission-product mixture in the various tissues (with the exception of the thyroid) appears to be dominated by one or a group of fission products, as seen from the similarity in the radioactive decay rates for all the tissues during the first 4 days. The thyroid, of course, has an affinity for iodine^{131} and the shorter-lived iodine radioisotopes.

A gamma spectrum analysis will be used in future experiments to identify the major fission-product components of the simulant material.

Following the administration of the simulant material by stomach tube, the radioactive decay of the material deposited in the various tissues (Fig. 3B) was very similar to that observed following the inhalation exposure. The basis for the similarity probably lies in the fact that in either mode of administration a large fraction of the radioactive material enters into the systemic circulation by the GI portal of entry.

Biological Loss of Simulant

The gamma activity of each tissue taken from mice sacrificed at various time intervals following exposure was corrected for radioactive decay back to 1 hr after exposure by the use of the above-mentioned radioactive decay curves. The resultant curve approximately describes the biological loss of the fallout simulant in that tissue (Fig. 4).

The activity of the GI tract and its contents decreased the most rapidly, due to the excretory nature of this organ. As previously noted,[4] the biological decay of the radioactive material in the GI tract was very rapid and could be separated into two components. The initial rapid loss of material with a few hour's half-life probably corresponds to the rapid loss of material from the GI tract via excretion. The second component with a half-life of several days was probably related to the slower pulmonary elimination of the lung "fixed" activity and to the normal excretion of internally deposited material. The rate constant for the loss of activity from the blood is also quite high initially, due to the rapid exchange of material from blood to other tissues. After this initial rapid loss, the activity in the blood approaches a constant level.

Following administration of the simulant by gavage, the material rapidly passed through the GI tract at approximately the same rate that was observed following inhalation. The rate of loss of the simulant through the GI tract was such that the stomach and small intestine contained 1 per cent of the maximum activity at 2 and 5 days, respectively, post-radiation. The activity in the large intestine fell to 1 per cent of the original activity by the 18th day.

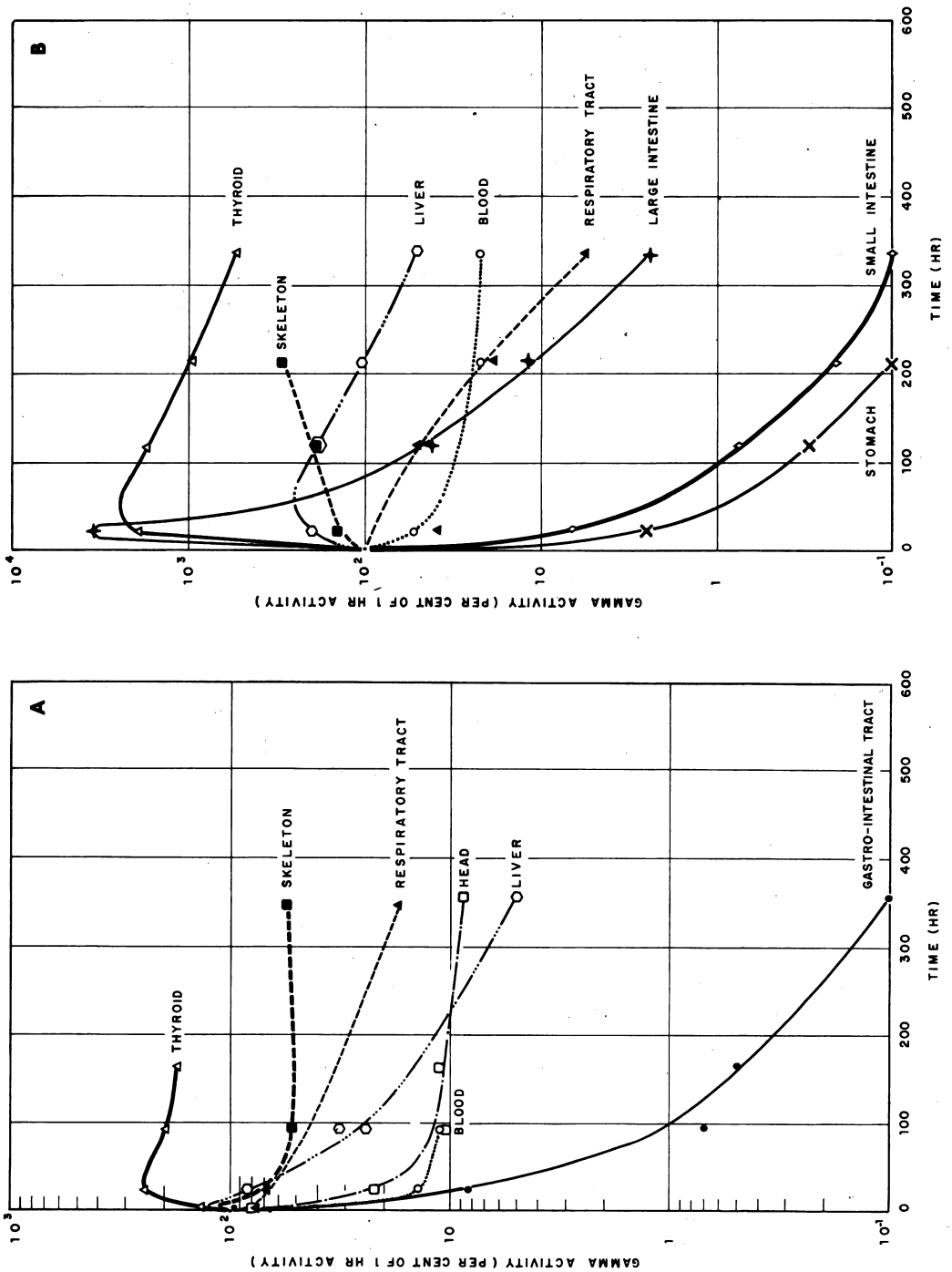

Fig. 4 Biological Decay of Fallout Simulant III in Tissues of Animals Following:

A. Inhalation Exposure

B. Administration of Simulant by Gavage

The very rapid clearance of radioactivity from the GI tract contrasts with the relatively slow biological loss observed in the respiratory system. At 5 days following an inhalation exposure, 42 per cent of the maximum activity of the respiratory tract is still present. The loss of activity from the lung for the first 15 days was approximately the same following the inhalation of simulants I and III. The curve of biological decay for the respiratory system can be described by 2 rate constants. The initial rapid loss of material (half-life about 10 hr) is probably associated with the rapid upward movement of material in the respiratory tract, while the second process (with a half-life of approximately 7 days) is probably associated with the slower loss of the smaller particles "fixed" in the alveolar tissue. With simulant III the biological decay of respiratory activity following administration of the simulant by gavage is much more rapid than that following inhalation (Fig. 4B) reflecting the different mode of fixation of the material in the lung. Following inhalation, a large fraction of the activity is on the air side of the alveolar membrane, while following gavage the material is deposited on the blood side of this tissue.

Following gavage, the activity in the liver built up to a maximum at around 3 days, in contrast to the more rapid build-up following the inhalation exposure. After 3 days the biological turnover of activity by this organ is the same for both modes of administration. For both types of administration the activity in the thyroid builds up to a maximum in 2-1/2 days, and then drops off.

With an inhalation exposure, the concentration of activity in the skeleton tapered off to a relatively constant value after an initial rapid loss. It stayed fairly level in the period 5 to 15 days. With gavage, however, the concentration appeared to increase in the 10-day period studied.

Evaluation of the Internal Radiation Hazard

While calculation of radiation dose from fallout with any degree of precision is difficult, an approximation based on experimental data is feasible and was performed here. In order to evaluate the dose to individual tissues following an inhalation exposure, the activity per gram tissue as a function of time was determined (Fig. 5). The greatest activity per gram tissue was observed in the thyroid at 1 hr following exposure. At this time the activity in the GI tract (including contents) was next highest, followed by that in the respiratory tract.

The total dose received by each organ for comparable energies is, of course, proportional to the area under its curve (see Table 3). The thyroid, for example, received 170 rad.* This was by far the highest dose received by any of the tissues measured during the 15-day experimental period studied. The ratio of the dose received by the thyroid to

* Calculation was performed by graphic integration.

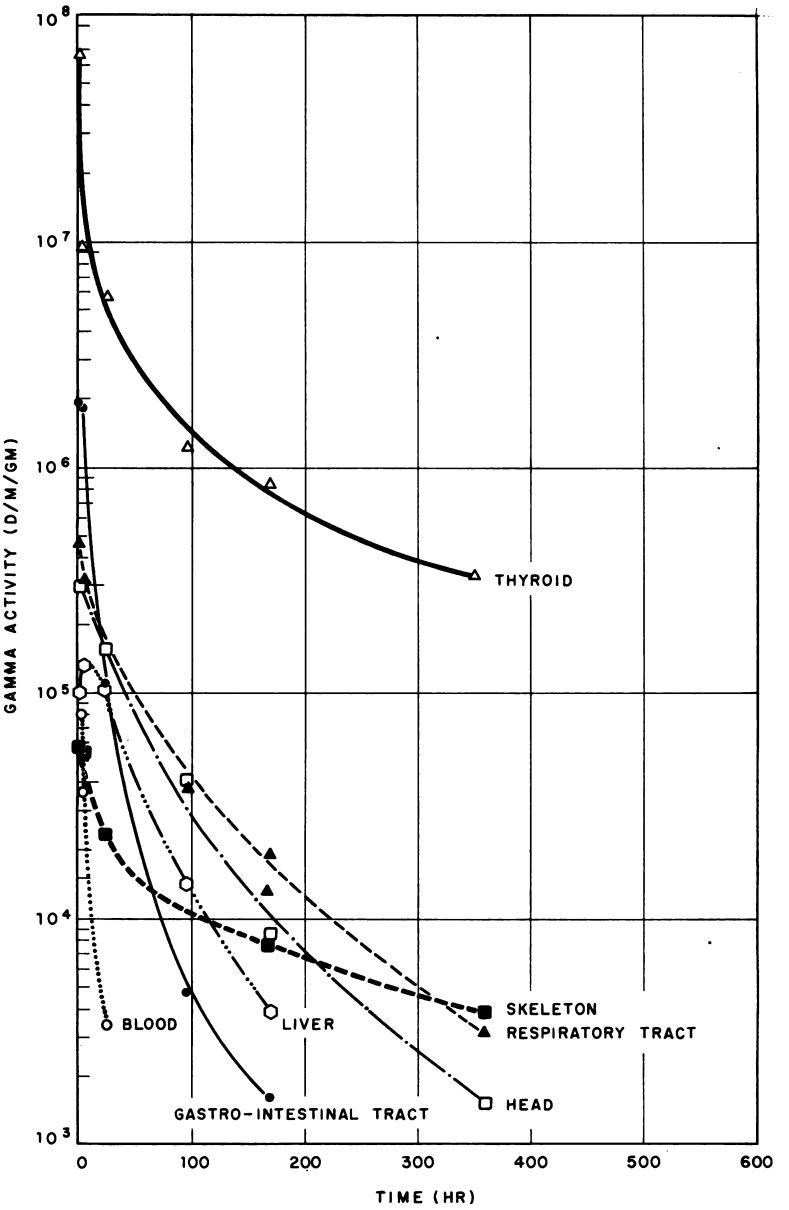

Fig. 5 Gamma Activity Per Unit Weight of Tissue Following Exposure to Simulant III

TABLE 3

Dose to Tissues From Internally Deposited Fission Products

Tissue	Dose Rate (rad/hr at 1 hr)	Total Dose	
		Interval (hr)	(rad)
Thyroid	16	0 - 360	170
GI Tract	0.96	0 - 168	16
Respiratory Tract and Lungs	0.24	0 - 360	8.0
Head	0.15	0 - 360	6.4
Liver	0.050	0 - 168	3.2
Skeleton	0.029	0 - 360	1.5

that received by the respiratory tract was much greater following exposure to the dry-particle simulant than following inhalation of the ionic simulant.

It is to be noted that, over an extended period, bone would receive the greatest integrated dose since the isotopes deposited in bone have half-lives ranging up to 27 years (Sr^{90}) and, in addition, have long biological half-lives. In contrast, the longest-lived iodine isotope has an effective half-life of 7.7 days and thus delivers its dose in a short period of time.

The dose rate to the individual tissues can be determined by use of the following formula:

$$I_t = K \frac{Q}{W} \bar{E}_\beta$$

where

I_t = dose rate in rad/hr

Q = beta activity of each tissue in d/min (gamma activity was measured experimentally in this study and was converted to beta activity on the basis that the ratio of gamma photons to beta particles at this time was approximately 1.2).*

* The following document is referenced for the convenience of those who have access to it. Sondhaus, C. The Ratio of Lung Beta Dose to Whole-body Dose During Given Time Intervals After an Atomic Bomb Detonation, U.S. Naval Radiological Defense Laboratory Report, USNRDL-394, 12 December, 1952 (CONFIDENTIAL).

W = weight of the tissue in gm

k = constant factor converting Mev to ergs, erg/gm to rad, min to hr, and gamma photons to beta particles: $(1.6 \times 10^{-6})\ (10^{-2})\ (6 \times 10)\ (1.2) = 1.15 \times 10^{-6}$.

Thus, the rate at which the deposited isotopes deliver a dose of radioactive energy to the thyroid at 1 hr after exposure can be calculated as follows:

$$\frac{\Omega}{W} = 6.8 \times 10^{7}\ \text{d/m/gm}$$

$\bar{E}_{\beta}$ = 0.2 Mev (the average beta energy for I^{131}, assuming the entire activity in the thyroid derives from this isotope).

$$I_{1\ hr} = (1.15 \times 10^{-6})\ (6.8 \times 10^{7})(2 \times 10^{-1})$$

$$= 16\ \text{rad/hr}$$

This calculation does not consider the tellurium precursors or the intake of tellurium isotopes. However, as pointed out by Dunning,[7] the error in ignoring these isotopes is not any greater than the other inherent uncertainties in this thyroid dose approximation. The short-lived iodine isotopes are not considered separately from I^{131} since the mean of the ratio of energies of I short-lived/I^{131} equals 1 at this time.[7]

The dose rate to the other tissues at 1 hr was also calculated (see Table 3). The value for $\bar{E}\beta$ for all tissues other than thyroid is approximately 0.39 Mev from 1 to 4 days post-detonation and 0.29 Mev from 4 to 15 days.*

The assumptions implicit in this calculation are first, the simulant is homogeneously distributed in the tissue and secondly, the energy is completely absorbed in the tissue. The energy absorption per tissue is taken, therefore, as equal to the energy emission.

Evaluation of the External Radiation Hazard

Since a simultaneous exposure of the animal to the airborne simulant occurs ordinarily with internal radiation, it is of interest to relate the internal dose with the concomitant external dose. In this particular experimental situation, however, the animals were not placed in the aerosol and thus the external dose could not be measured directly. The

* See footnote on page 14.

following calculation applies only to the general case. It is to be noted that, in this calculation, a homogeneous distribution in the aerosol is assumed, and an infinite volume of aerosol is also implied. It is to be noted further that for calculation of the external dose the gamma radiation is of primary importance, while the internal dose is based on the beta radiation. An approximation of the external dose rate at 1 hr that would have been received by these mice had they been exposed to this aerosol in a 2π field can be calculated as follows:

$$I_t = 51 \frac{Q}{W} \bar{E}_\gamma$$

where

I_t = dose rate, rad/day

$\frac{Q}{W}$ = activity, μc/gm

$\bar{E}_\gamma$ = average gamma energy, Mev.

Thus, for

$\frac{Q}{W}$ = 32 μc/gm and E = 0.65 Mev/dis,*

$I_{1\,hr}$ = 1060 rad/day or 44 rad/hr in a 4π field

= 22 rad/hr in a 2π field.

The integrated dose that the mice would receive externally when exposed for 3 hr to the same aerosol in a 2π field is approximately 60 rad. The ratio of the external dose to the dose received by the lung from the internal emitters was 8, which corresponds closely to theoretical calculations.*

SUMMARY AND CONCLUSIONS

The present study was designed to reproduce in the laboratory an acute exposure of mice to early fallout (2 days old) such as might result from a land-based nuclear detonation. Biological data were obtained on

* See footnote on page 14.

the uptake, distribution and retention of the inhaled fallout simulant. Further, as a basis for comparing the effects of different types of simulants, the metabolic behavior of this dry-particle fallout simulant of limited solubility was compared with that of two previously studied fallout simulants; an ionic liquid aerosol and a mud-slurry aerosol. The simulant was also administered by gavage to provide data on the uptake of fallout by ingestion as compared with inhalation.

Following a 3-hr exposure to the dry-particle simulant, activity was quickly cleared from the lungs and appeared primarily in the GI tract. Lesser concentrations of activity were also found in the head, liver, skeleton and thyroid. The radioactivity was removed very rapidly from the GI tract, as compared to the rate of loss of the simulant from the respiratory system.

The ratio of activity in the GI tract to that in the respiratory system following exposure to the ionic, mud-slurry and dry-particle simulants was 3.2, 12 and 80, respectively. The rate of biological elimination of the dry-particle simulant material from the skeleton and liver was considerably greater than was noted with the previously studied ionic simulant. In terms of total respiratory and GI tract activity at 1 hr, the skeletal activity was twice as high for the ionic simulant as for the dry-particle simulant, while the reverse was true for the liver activity.

Following the administration of the simulant by gavage, the initial distribution of activity in the GI tract and in the tissues was very similar to that following inhalation exposure. It was found that the absorption across the GI tract provided an important portal of entry for the dry-particle simulant into the systemic circulation following an inhalation exposure. The composition of the simulant material in the various tissues during the first 4 days following exposure appears to be dominated by one or a group of fission products, as seen from the similarity of the radioactive decay rates for most of the tissues. The results were similar for both inhalation exposure and administration by gavage. Exceptions to these findings were the thyroid and skeletal tissues, the former having an affinity for the short-lived iodine isotopes, and the latter for the longer-lived fission products.

The thyroid received the highest dose to any tissue from the internally deposited fission products. The GI tract received the next highest dose, which was, however, less than 10 per cent of the dose to the thyroid. The dose to the skeleton, while lowest in the 15-day period studied, will probably be greater than that to other tissues over a longer period of

time since the skeletal activity falls off more slowly than that in other tissues. The internal radiation dose to individual tissues was, with the exception of the dose to the thyroid, lower than the concomitant external dose received by the animals.

Approved by:

A.R. BEHNKE, Jr.
Captain (MC) USN
Acting Head, Biological and
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For the Scientific Director

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